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MINERAL RESOURCES

OF

BLAND COUNTY

IN

SOUTHWESTERN VIRGINIA

BUILDING STONES (Granite, Syenite, Gneiss, Mica Schist, Trappean Rocks, Slate, Sandstone and Limestone), Non-Metallic Minerals (Pyrite, Pyrrhotite, Arsenopyrite, Fluorite, Silica, Ocher, Manganese, Feldspar, Asbestos, Talc and Soapstone, Fullers Earth, Barite and Gypsum), Mineral Waters, Cement Materials, Clays, Sand and Marls, Copper, Zinc and Lead, Iron and Coal.

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MINERAL RESOURCES

OF

BLAND COUNTY

IN

SOUTHWESTERN VIRGINIA

BY

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MINERAL RESOURCES
OF
BLAND COUNTY,
SOUTHWESTERN VIRGINIA

The range of mineral occurrence in Southwestern Virginia and especially in the mountain county of Bland is wide and varied, comprising within its scope *Building Stones* (granite, syenite, gneiss, sandstone and limestone), *Non-metallic Minerals* (pyrite, pyrrhotite, arsenopyrite, fluorite, silica, ocher, manganese, feldspar, asbestos, talc and soapstone, fullers earth, barite and gypsum), *Cement Materials, Clays, Copper, Zinc and Lead* (sphalerite, calamine and galenite), *Iron Ores* (oriskany, hematite, magnetite and limonite) and *Coal* (bituminous, semi-bituminous, Pocahontas, Montgomery-Pulaski and Bland-Wythe fields) of the highest steam and coking grade.

Iron ore occurs in deposits of remarkable richness, the beds of ore being from 20 to 100 feet in thickness and many miles long. The western foothills of the Blue Ridge are lined with brown hematite ore, solid masses of it appearing along the Alleghenies. The yield of brown hematite from this region comprises an important precentage of the total output of this variety in the County, and also constitutes the bulk of iron ore production in the State. The lead and zinc deposits of Wythe County, adjoining Bland County, have been worked for more than 125 years, and furnished lead to both the Continental and Confederate Armies. Copper deposits are extensive in Southwestern Virginia and numerous noted deposits have long been the seat of an important industry. The sandstones of the Mountains, the limestones and slates of the Valleys, and the granites and cement materials which are widely distributed afford an abundant supply of building materials. From the fertilizing marls and greensands of Tidewater westward to the vast coal and metalliferous deposits near the Kentucky and West Virginia lines, is spread a great variety of mineral wealth, which affords such basis as to make the mining industry an important factor in the industrial activity of the State. The mining of coal in Virginia began in 1775, near Richmond. From the beginning of this industry until 1789, the entire output went to supply the local demand. From this time until the building of the Norfolk and Western Railway in 1882, the annual shipments from Virginia have increased up to about 145,000 tons, and then followed the development of the great coal deposits of Southwestern Virginia, notably the Pocahontas region, and the State soon came into prominence as a great coal producer, the most important deposits being in the great Appalachian region. The most remarkable and valuable occurrence of bituminous coal to be found

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in the United States in association with vast deposits of metalliferous ores is that forming the Southeastern portion of the Kanawha basin, comprising Tazewell, Russell, Scott, Buchanan, Wise and Lee Counties, and extending into Bland County. Limestones, dolomites and pyrite are the predominating deposits of the region west of the Blue Ridge. The limestones have been quarried extensively at numerous places, but have been used to only a very limited extent for building purposes, most of the output being utilized for making lime and as a flux in the reduction of ores. The bulk of the extensive pyrite deposits, so far mined in Southwestern Virginia, has gone into the manufacture of sulphuric acid, the demand for which commodity having increased materially of late, as a result of its extended use in the manufacture of paper from wood pulp, and the manufacture of superphosphates from phosphate rock, in which latter process a chemically pure sulphuric acid is not essential and that made from pyrite serves the purpose equally as well as that made from sulphur. In the production of pyrite, Virginia takes first rank. Siliceous crystalline rocks and slate cover a large area in Southwestern Virginia. The production of building stone of fine quality has become an important industry, and the output of the Virginia granite quarries has been used in many notable structures, and is well adapted not only for general building purposes, but for paving stone and monumental work. This granite has found a market in practically all the states and cities south of New England and as far west as Nebraska. The occurrence of slate in deposits of commercial importance is distributed over a considerable area in Bland County and Southwestern Virginia, excellent deposits having been found and developed in the Great Valley and Appalachian districts. The beginning of manganese ore mining in Virginia, and perhaps in the United States, occurred in 1857. For many years the States of Virginia and Georgia have contributed the bulk of the output of this valuable mineral in the United States, nearly all the yield being exported to England. The known occurrences of manganese ore in Virginia are widely distributed, being practically co-extensive with its area. Beginning with the pocket occurrences in the Tidewater district. the ore has been found and mined in the Midland, Piedmont, Blue Ridge, Valley, Appalachian and trans-Appalachian divisions, westward to the West Virginia line. All the foregoing and other minerals occurring in Bland County and Southwestern Virginia, including Timber Estimates, are set forth in detail with the requisite assays and estimates, locations and exploitation notes.

BUILDING STONES.

The production of building stone in Virginia has long been an important industry, and the output in granite and other varieties has been used in many notable structures. An abundance of excellent building and decorative stone occurs throughout the Mountain provinces of the State. These include granite and gneiss; trappean rocks; slate; sandstone and quartzite; and limestone.

Granite.—Crystalline, granular, massive rocks, consisting essentially

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of quartz, orthoclase, and mica or hornblende, occur in Little Walker Mountain and in the Mountain districts of Southwestern Virginia.

FIGURE 1.—DISTRIBUTION OF CEMENT MATERIALS OF THE NEW RIVER DISTRICT, SOUTHWESTERN VIRGINIA.

In the vicinity of No Business Creek there are outcrops of a light

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gray biotite granite which appears to have been extensively altered by pressure, and according to the degree of alteration the rock is a granite, gneiss, or quartz schist.

Syenite.—An exposure of hornblende syenite, strikingly similar to the syenite of Madison and Greene Counties, has been traced for more than a mile on the eastern slope of Wolf Creek Mountain, near the northwest boundary of Cluxi. It is indicative of a large area of coarse-grained dark greenish aggregate of feldspar and black pyroxene, and shows pronounced crushing and shearing from pressure. This syenite would prove a desirable stone for general construction work.

Gneiss.—Excellent exposures of gneiss are found along New River and some of its tributaries above Pearisburg. South of New River and extending into Bland County towards Rich Mountain are several belts of granite-gneiss of uniform color and texture, in which quartz, feldspar and mica are the predominating minerals. An exposure near Laurel Creek is of such character as to be readily dressed and split into slabs and is quite resistant to atmospheric agents.

Mica Schist.—Rocks composed essentially of quartz and mica, with pronounced schistose structure, similar in grade to mica schist quarried in Franklin County and well adapted for flagging and other purposes, outcrop along Hunting Camp Creek, and are traceable in the direction of the source of No Business Creek in western Giles County. The rock is thinly foliated, and composed essentially of mica and quartz and a variable quantity of feldspar.

Trappean Rocks.—Numerous basic eruptive rocks without distinctive significance in mineralogical composition, of finer crystallization than granite, but well suited for general building and ornamental work, occur widely distributed over parts of Bland and adjacent Counties. An outcropping between Kimberling and No Business Creeks, resembles in many respects a granitoid igneous rock composed of plagioclase feldspar and pyroxene found in Amherst County, east of Lynchburg, and in the northwestern part of Floyd County.

Slate.—Argillaceous rocks are exposed in several sections of Bland County, in contact with granites and gneisses. These rocks, through the process of shearing and incidental chemical activity, have undergone a partial metamorphism, resulting in the development of pronounced tendency to split along certain planes. An outcropping on No Business Creek shows a black slate of moderately fine texture and little lustre very similar to that quarried in Farquier County, which is carbonaceous, shows pyrite, has no magnetite, does not effervesce with cold dilute hydrochloric acid, and has an argillaceous odor.

Sandstone.—Cambrian, Silurian, Devonian and Carboniferous sandstones, in association with quartzites or metamorphosed sandstones, are generally distributed throughout Southwestern Virginia. They are well exposed in Bland and Pulaski Counties and show a variable thickness of sandstone, shale and conglomerate. They have been quarried in Pulaski County and used for building material in the Town of Pulaski and elsewhere. Groups of these rocks comprise a great thickness of alternating beds of shales and conglomeratic sandstones, with beds of coal. The rocks are distributed over the southwest corner

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of the State along the Kentucky and West Virginia lines, and include the whole or parts of Lee, Scott, Russell, Wise, Dickenson, Buchanan, Tazewell and Bland Counties.

Limestone.—Bland County has an abundance of Ordovician limestones and shales. Those exposed between the Walker Mountain and Saltville faults cross Bland County in a northeast and southwest direction, outcropping just northwest of Walker Mountain. A notable area of outcrop is a strip following the foothills of the northwest side of Rich Mountain. Northwest of this strip the Knox dolomite is thrust over higher rocks, this fault being the northeast extension of the Copper Creek fault. The succession and character of the Ordovician rocks in Bland County are quite similar to those of the same age in Scott, Russell, Tazewell and Giles Counties. The distribution of Ordovician limestones and shales in the vicinity of Cluxi and Pearisburg is shown in Figure 1. An extensive outcrop near the head of No Business Creek, similar in all respects to the Chickamauga formation at Ripplemead, Va., gave the following analysis:

Calcium Carbonate	91.17	per cent.
Magnesium Carbonate	5.03	" "
Iron Oxide	1.29	" "
Silica	1.08	" "
Organic Matter	1.43	" "

Samples selected from various horizons of the Chickamauga limestone in this section show a uniform chemical composition.

NON-METALLIC MINERALS.

Bland County and Southwestern Virginia are rich in non-metallic minerals—sulphides, sulpharsenides, halides, oxides, silicates, phosphates and sulphates.

Pyrite.—The mineral pyrite, commonly known as iron pyrites, is widely disseminated and occurs in contact positions between eruptive and sedimentary masses, as fissure veins and as lenticular bodies lying conformably with the foliation of the enclosing rocks. The ore bodies are generally marked by rolls and swells and by pinching and narrowing, and their contact with the wall-rock is sharply defined. The mineral species associated with the pyrite lenses or ore-bodies include both metallic and non-metallic compounds (blende, chalcopyrite, galena, pyrrhotite and magnetite, calcite and quartz). A specimeu from an opening between Wolf Pen Branch and No Business Creek shows the following composition of the pyrite:

Sulphur	47.13	per cent.
Iron	43.88	" "
Iron Oxide	1.16	" "
Silica	6.61	" "
Zinc	.83	" "
Lime	.39	" "

Traces of copper, in the form of chalcopyrite, are also present intermingled with the pyrite. In accounting for the origin of these

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ore-bodies the State Geologist suggests a replacement of limestone by the sulphides.

Pyrrhotite.—Magnetic pyrites or Mundic, common names for pyrrhotite, is found scattered throughout Southwestern Virginia, the largest concentration of the mineral being that of the *Great Gossan Lead* in Floyd, Carroll and Grayson Counties. The profile of this lead, showing gossan (limonite) reserves, is seen in Figure 2. It is not in every place a solid mass of pyrrhotite from wall to wall, but rather a series of layers, partly of pure pyrrhotite and mixed with micaceous material. The vein-filling in many places comprises rock fragments of varying character cemented by the sulphides. These fragments are generally well rounded; sometimes subangular and include rock types not seen on the surface. The pyrrhotite occurs in isolated areas, but in more or less regular leads, the widths of the leads being variable. An outcropping on the western slope of Flat Top Mountain, above No Business Creek, shows about 33 per cent. sul-

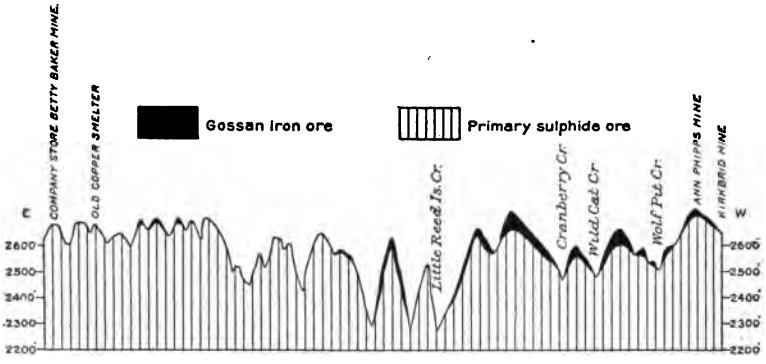

FIGURE 2.—PROFILE OF "GOSSAN LEAD," SHOWING GOSSAN (LIMONITE) RESERVES.

phur and about 53 per cent. iron. An extensive plant has recently been completed at Pulaski for the purpose of utilizing pyrrhotite for the making of both acid and iron.

Arsenopyrite.—This double sulphide of arsenic and iron is found in association with pyrite and traces of cassiterite in veins which outcrop in places along the slopes of Flat Top and Wolf Creek Mountains. Numerous lenses have been uncovered, increasing in size towards No Business and Kimberling Creeks and rapidly widening as depth is attained. These veins or lenses are similar in all essentials to the Floyd County aresenopyrite deposits, which have been exploited with profit and satisfaction, one drift extending to an 8-foot vein or lens of arsenopyrite, of 25 per cent. arsenic.

Fluorite.—Fluorspar (fluoride of calcium) the commercial designation of fluorite is sparingly found in the Cambro-Ordovician limestone of Southwest Virginia in association with the ores of zinc and lead. Various occurrences have been noted on the slopes of Flat Top, Sugar Run, Wolf Creek and Brushy Mountains. The close association of the veins with dykes of igneous rocks makes it reasonably certain that the ores are genetically related to the igneous intrusions. The

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evidence of such relationship is strengthened when the composition of the gangue and the metals is considered. The principal and abundant gangue mineral, fluorite, and the metallic sulphide, argentiferous galena, with traces of arsenic and antimony, constitute an association of minerals such as can best be explained on the supposition of highly-heated conditions. Such could have been deposited only from waters of deep-seated origin, or from waters whose source of heat was derived from intruded igneous masses.

Silica.—Quartz, chert and diatomaceous earth are widely distributed over Southwest Virginia. Quartz is the most common in massive-granular form and occurring as veins in the older crystalline rocks. Its principal occurrence in Bland County is as a chief constituent of pegmatite dikes and veins penetrating the older metamorphic rocks. Chert, frequently known as hornstone, is a chalcedonic variety of silica, and has wide distinction in the form of irregular nodular masses of light, red, brown and black colors. Diatomaceous earth, resembling chalk and kaolin in its physical properties, has a predominant siliceous character. Its deposits are formed from the shells and tests of certain aquatic microscoping forms of plant life, known as diatoms, which have the power of secreting silica in the same manner as mollusks secrete lime carbonate. The siliceous character of diatomaceous earth from an opening north of Laurel Creek, at Cluxi, is shown by an analysis giving 73.18 per cent. silica, 3.12 per cent. alumina and 14.01 per cent. water and organic matter.

Ocher.—The earthy and pulverulent forms of hematite and limonite (anhydrous and hydrous oxides of iron) have wide variation in mode of occurrence in Southwest Virginia and are rendered more or less impure through the presence of other metallic oxides and argillaceous or clayey matter. Ocher, resulting from the leaching action of percolating waters and subsequent deposition, from the decomposition of rocks rich in non-bearing silicate minerals, from the oxidation of pyrite, from the decomposition of the hematite and from the alteration of the compact forms of limonite, is found in Bland and adjacent Counties in more or less purity. That prospected at and near Cluxi, east of No Business Creek and along the North Fork of Kimberling Creek, is unusually fine and free from impurities, the colors ranging from yellow to gray. The analysis of a sample from near the western base of Flat Top Mountain, between Holly Brook and No Business Creek gave:

Ferric Oxide	49.17	per cent.
Manganese Oxide	1.94	" "
Clay and Sand	41.11	" "
Water	4.78	" "

In this locality a series of ochers of various colors and excellent quality are apparent along the outcrops.

Manganese.—Virginia has more known deposits of manganese than any other State of the United States, the richest being in the Paleozoic area or Mountain province. In Bland County the ores are, generally speaking, embedded in the residual clays which overlie the rocks, from which the clays have been derived by the usual processes of decay,

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the underlying rock being either the usual consolidated sediment, sandstone, shale, or limestone; or, a metamorphic crystalline type. Closely associated with the manganese deposits and co-extensive with them there are numerous deposits of limonite. The ore-bearing rocks are of Cambrian and Ordovician age. In some places the manganese ore is sufficiently abundant to form a manganiferous iron ore, or even a ferruginous manganese ore.

In the principal deposits the ores are found in large masses, consisting of a mixture of psilomelane and limonite in varying proportions with decomposed sandstone and clay in the form of small fragments and irregular masses. The ore is deposited around the fragments, and in veins through them. Where the clay is sandy, the ore contains an abundance of sand grains. The relation between the iron and manganese is complex, though most frequently the manganese penetrates deeper into the mass. Limonite generally lines cavities in the manganese ore, and in such places it is doubtless a later deposition. On the main ridge of Flat Top Mountain, overlooking No Business Creek, there is a deposit very similar in appearance and occurrence to the manganese ore in the Cave Spring district at Reynolds Mountain in Floyd County, Georgia. The ore is a bluish psilomelane, with granular pyrolusite, cementing fragments in chert breccia, Figure 3, exposed in dark-red clay. The breccia masses vary in size and are of irregular shape. Some are composed largely of chert with a few veins of ore filling cracks, while others consist largely of ore with scattered chert fragments. All variations are found between these extremes. The ores are uncommonly hard, have botryoidal surfaces in many cavities, contain quartz seams, and are most abundant around the surface of brecciated chert masses between the clay and the more solid interior of the mass. An analysis of this ore shows the following composition:

Metallic Manganese	50.71	per cent.
Metallic Iron	8.43	" "
Phosphorus	.09	" "
Silica	11.31	" "

Several theories have been advanced regarding the origin of these Appalachian manganese ores, appearing in Bland County and adjacent territory; but, doubtless the Cambrian and Ordovician sediments were obtained from the disintegration and decomposition of the crystalline and metamorphic rocks. These rocks contained manganese-bearing silicates, such as micas, pyroxenes, amphiboles, and garnets, which were either deposited undecomposed in the shales and to a small extent in the quartzites, or were decomposed and had their manganese content carried in solution and deposited as oxide or carbonate in the shales or limestones. After the sediments emerged from the sea and were consolidated, erosion took place, and during this process the manganese was dissolved, carried downward by percolating waters, and deposited in favorable localities, such as were formed locally by underlying impervious layers or by fault planes. As erosion continued the ores were continually carried downward, being often redissolved and deposited elsewhere, giving rise to veins

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and replacement deposits of pyrolusite in sandstone and sandy clay masses and also to breccia ores and other forms.

Feldspar.—Pegmatitic dikes of frequent occurrence through Southwestern Virginia contain feldspar of the potash varieties, orthoclase and microcline. Occasionally the soda variety, albite, occurs. The feldspar is associated with quartz and mica as coarse crystallizations. Orthoclase, the most ordinary variety, from Pearis Mountain, near the head of No Business Creek, gave the following typical analysis: Silica, 63.18; alumina, 20.33; alkalies, 15.17; and water 0.69.

Asbestos.—Amphibole asbestos is found sparingly in the granite or schistose rocks of Bland County in pockets and occasionally in

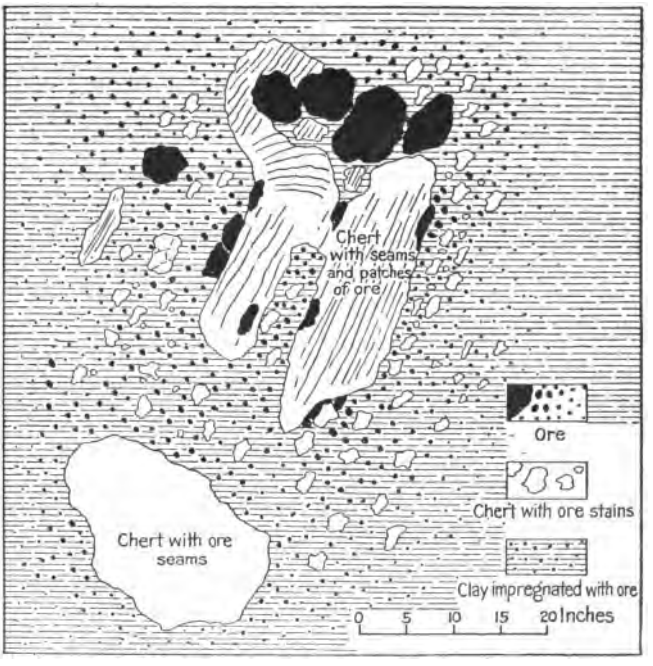
Chert with seams and patches of ore
Ore
Chert with ore stains
Chert with ore seams
Clay impregnated with ore
0 5 10 15 20 Inches

FIGURE 3.—OCCURRENCE OF BRECCIA ORE AT REYNOLDS MOUNTAIN.

well-defined veins as occurs in the vicinity of Kimberling and Laurel Creeks. Chrysolite or serpentine asbestos occurs sparingly associated with the outcrops of basic magnesian rocks, more or less altered to secondary serpentine. Amphibole asbestos, occurring in ancient crystalline rocks that have been crushed and sheared under great pressure in the process of mountain building, appears in three forms. Two of these forms, slip fiber and cross fiber, are veins, and the third is found in large fibrous masses, generally made up of small bunches of asbestos which are more or less divergent and sometimes distinctly radial. In veins of slip-fiber asbestos the fiber lies parallel to the vein walls and marks a plane of fracture along which the two sides have slipped upon each other and given direction to the development of the fiber.

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Talc and Soapstone.—The pure form of talc (hydrous silicate of magnesia) rarely occurs in commercial quantity; but, soapstone (steatite an impure form of talc) has a wide distribution among the older crystalline rocks, in some cases being derived from altered eruptive rocks, and in others probably being derived from magnesian sediments by metamorphism. Deposits of foliated talc, associated with limestone and basic magnesian rocks, have been located in Bland and Giles Counties, in numerous localities. Where the pyroxenite variety of these basic magnesian rocks has been converted into the secondary rock composed almost entirely of the steatite variety of talc, the deposits are indicative of great commercial possibilities. An outcropping of soapstone of good quality is found between No Business Creek and Wolf Pen Branch. Exposures of the rock show a thinly foliated hornblendic schist and exposures of diabase in close association with the soapstone.

Fullers Earth.—Among the clays of Bland County are found a variety of clay like substances, which have strong absorbent properties, and which result from the decomposition of the hornblendes and augites rather than the feldspars. Outcroppings, on the slopes, around the edges of low places at and near No Business Creek, are indicative of large areas of fullers earth. The analysis of a selected sample is as follows:

Silica	59.32	per cent.
Alumina	16.17	" "
Ferric Oxide	2.08	" "
Lime	2.11	" "
Magnesia	2.81	" "
Water	17.51	" "

Heretofore but little fullers earth has been located in or near this territory and the simplest methods have been used in preparing the material. When these areas are topograpically surveyed and the deposits mapped, they will doubtless compare favorably with the Florida and Georgia beds as is indicated by stratigraphic relations and lithologic characters. A practical test has shown that mineral oil was bleached quite nearly to the standard shade, while the material developed with cotton-seed oil bleaching qualities quite equal to the English material.

Barite.—The sulphate of barium, commercially known as barytes, is found widely distributed in Southwest Virginia, occasionally occurring in well-defined veins, but more often found in a series of pockets or lenses of varying dimensions. These are more or less in line, often following the dip of the limestone or other rock with which they are associated. The deposits of the Mountain region, in Bland, Tazewell, Russell, Wythe, Washington, Scott, Smith, Montgomery, Botetourt, Rockbridge, Warren and Frederick Counties, are associated for the most part with the Shenandoah limestone or its residual clay. Where the barite occurs in the limestone it is generally found as superficially loose lumps and nodules of irregular shapes and sizes. In the Bland-Tazewell-Russell area the usual associates are calcite and limonite, with some fluorite and small cherty masses. The ore has

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been tested to a depth of more than 100 feet without any indication of its exhaustion. In the vicinity of Cluxi, barite occurs in a series of lenticular pockets which have a general northeast-southwest strike and dip towards the east. At times the pockets are distinct from each other, and again they are connected by thin seams of barite. The barite is free from galena and but slightly stained with iron oxide.

Gypsum.—In Southwest Virginia the principal gypsum producing locality is confined to a portion of the valley of the North Fork of Holston River, where the deposits of Plasterco and Saltville furnish the principal output. The deposits are associated with grayish clays in shales and limestones of Lower Carboniferous age. The State Geologist has concluded that this narrow belt is composed of the Greenbrier limestone (Lower Carboniferous), and the beds of salt and gypsum. Indications of gypsum of excellent quality have been noted near Kimberling Springs and along Kimberling and No Business Creeks, where more extended underground examinations will undoubtedly demonstrate the occurrence of deposits of commercial importance.

MINERAL WATERS.

The mineral waters of Virginia are an important source of revenue, the State being second only to New York in the number of springs that are utilized commercially. Some of these waters contain mineral salts in such proportion as to give them medicinal value, while others are exceedingly pure and used solely for table or domestic purposes. The following springs in Southwest Virginia are well known:

Alleghany Spring, Alleghany Springs, Montgomery County; Crockett Arsenic Lithia Spring, Crockett Springs, Montgomery County; Hunter Pulaski Alum Spring, Walkers Valley, Pulaski County; Iron Lithia Springs, Tip Top, Tazewell County; Nye Lithia Springs, Wytheville, Wythe County; Wyrick Spring, Crockett, Wythe County. The analysis of a spring located on No Business Creek, at Cluxi, about 2,150 feet above sea level, shows the following contents, in relation to one gallon of 231 cubic inches:

Magnesium Sulphate	1.31	grains.
Calcium Sulphate	1.62	"
Iron Sulphate	4.12	"
Aluminum Sulphate	6.41	"
Silicic Acid	1.09	"
Sulphuric Acid	0.52	"

together with traces of sodium chloride and potassium, sodium and manganese sulphates.

CEMENT MATERIALS.

The most important cement materials of Western Virginia are found in pure and argillaceous limestone of Cambrian and Ordovician age, and in the calcareous and argillaceous phases of the Ordovician shales. These shales and limestone have a wider distribution and are more generally accessible than any other cement rock horizons of the

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State. Bland County and in fact the entire Valley of Virginia is underlain by these limestones, the shales outcropping all along the bases of the bounding mountains. There is a similar exhibition of these limestones and shales in most of the valleys west of the Great Valley. From a geological standpoint, Southwest Virginia may be considered as composed of elongated, narrow, northeast-southwest blocks, in each of which strips exposing cement materials are found. The general distribution of cement-making materials is shown in Figure 1. As there indicated, four important areas of limestones and shales are seen, each area being crossed by or within short distance of a railroad. Many springs in this territory contain carbonate of lime in solution. These have been and are still depositing calcareous tufa, which when located in sufficient quantity will be of great value in cement manufacture. The area between Flat Top and Wolf Creek Mountains, and especially in the vicinity of Cluxi, is prominent as a region containing the raw materials for the making of cement; but, comparatively little has heretofore been noted or published upon its detailed stratigraphy.

CLAYS.

Both residual and sedimentary clays are distributed throughout Southwest Virginia, in deposits of variable thickness, and the decomposition of pegmatite veins yields large quantities of kaolin free from iron and of high grade. The following is an analysis of a deposit near Burton's Branch of No Business Creek, Bland County, after washing:

Silica	43.92	per cent.
Alumina	41.17	" "
Ferric Oxide	1.71	" "
Lime	1.11	" "
Magnesia	0.64	" "
Alkalies	2.61	" "
Water	8.84	" "

Good beds of ball clay, fire clay, vitrified ware clay, brick clay, slip clay and paper clay have been exploited near Cluxi, between Flat Top and Wolf Creek Mountains. The Mountain province of Virginia contains clay resources of very great value. Associated with the coals are beds of shale which after investigation and development will become a valuable source of revenue.

SAND AND MARLS.

Glass, moulding, and building sands occur in commercial quantities throughout Southwest Virginia. Bland County has a wide distribution of deposits in considerable quantities along its stream courses. Between Kimberling and No Business Creeks there are large beds of glass sand, comparatively free from iron, copper, clay, magnesia and organic compounds, which show by analysis as follows:

Silica	99.573	per cent.
Alumina	.194	" "
Oxide of Iron	.012	" "
Limestone and Magnesia	.036	" "
Volatile Matter	.185	" "

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Oxide of iron, even in larger quantity, reacts very slowly with silica, in the presence of steam under pressure; it may therefore be considered inert except for its coloring action, unless it acts as a promoter of chemical combination, as is the case with ferric oxide in the manufacture of Portland cement.

Both calcareous and greensand types of marl are developed throughout the Valley region of Virginia, west of the Blue Ridge. These marls are mixtures of calcium carbonate and clay, occurring naturally with more or less siliceous sand, sometimes compact and sometimes pulverulent.

COPPER.

The geologic conditions are quite unlike in the different copper areas of Virginia. In Southwest Virginia, the "Gossan Lead" of the Floyd-Carroll-Grayson plateau, Figure 2, is indicative of the character and mode of occurrence of deposits in neighboring localities. As a rule the rocks are mostly altered sediments, and faulting of the overthrust type predominates. Several small outcrops on the eastern slope of Wolf Creek Mountain, Bland County, consist essentially of pyrrhotite with stringers of chalcopyrite. The pyrrhotite is more or less admixed with micaceous material, and in places interleaved with talc. The *Betty Baker, Cranberry, Kirkbride, Vaughn, Copperas Hill, Chestnut Ridge, Wolf Pit* and *Wild Cat* mines demonstrate the continuity of the veins, the richness of deposits and extensive areas of mineralization. Numerous good specimens of bornite, chalcopyrite and malachite, have been obtained from openings in schists, not far removed from porphory contacts in Buckhorn, Rich, Wolf Creek, Brushy, Flat Top and Little Walker Mountains.

LEAD AND ZINC.

The ores of lead and zinc in Bland County and adjoining territory range from Lower Cambrian to Carboniferous in age, and are of sedimentary origin. According to the State Geologist, as set out in the Bulletin of the American Institute of Mining Engineers, they include shales, sandstones, conglomerates and limestones, and have been more or less metamorphosed and consequently considerably changed, as a rule, both lithologically and structurally. Folds and faults characterize the entire area of the Great Valley of the Virginia-Tennessee district. The folds have a general trend paralleling approximately the axis of the Valley, which is northeast-southwest in direction. The dips on the western side of the anticlines are frequently vertical, and in places overturned, and many of the folds have been compressed until broken. The faults are associated with the anticlinal folds, the breaks occurring usually on or near the northwestern side of the anticlines. The faults are of over-thrust type, with the fault planes usually dipping from 30 to 50 degrees southeast. The faulted zone is characterized by much brecciation, and it is along these zones that localization and concentration of the lead and zinc ores have taken place.

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Geographically, the ores are confined to the valley region of Southwest Virginia and its equivalent in Eastern Tennessee, extending from Roanoke, Va., southwestward to Knoxville, Tenn. Geologically, the ores are confined to a single formation, magnesian limestone of Cambro-Ordovician age, known as the Shenandoah limestone in Virginia, and the Knox dolomite in Tennessee. The Shenandoah limestone is correlated with the Knox dolomite, and includes, in addition, at least, 1,500 feet of Cambrian strata beneath the Knox dolomite.

These ores comprise the following minerals: (1) The original sulphide forms, sphalerite, galenite, pyrite, and chalcopyrite; and (2) the secondary or oxidized forms which have been derived from the original sulphides and occurring in the residual decay of the limestone. These include calamine, smithsonite, cerussite and limonite. The associated non-metallic minerals, named in the order of their importance, are dolomite, calcite, barite, fluorite and quartz. Of these, the dolomite and calcite take precedence, occurring in large amounts.

The bulk of the sulphide ores belong to the disseminated replacement breccia type. As a rule, the process of replacement has played an important part in the ore formation, but in some instances very little replacement of the limestone by the ore is indicated. In the latter case the ore would be more properly designated a straight breccia type in which practically no replacement has occurred. On the other hand, the ore has originated at several places over the district largely through a replacement process.

The breccia is usually made up of sharp-angled fragments of the country rock, magnesian limestone, cemented by a matrix of white crystallized calcite, and dolomite and blende, with or without replacement of the limestone fragments, as shown in Figure 4. The breccia zones are associated with faulting and folding. Not all parts of the breccia zones are mineralized, but the ore is distributed at somewhat irregular intervals. Where mineralized, and so far as can be judged, the ores continue with depth.

Where sufficient developments have been made, as in the mines of Wythe County, the oxidized ores usually show much richness, and they are often concentrated in massive form as large irregular masses and layers. This is especially true of the calamine, which forms the dominant oxidized ore. So massive was the calamine in places in the old Bertha mines, that blasting is reported to have been necessary at the time for its removal.

Concentration of the oxidized ores has taken place principally at and near the bottom of the residual clays, closely hugging the irregular weathered surface of the limestone. Frequently several inches of clay separate the massive form of the ores, calamine and smithsonite, from the limestone. This space is oftentimes filled, however, with a loose powdery form of admixed calamine and smithsonite. Cerussite occurs largely in stringer form, penetrating the clays next the limestone surface and as a coating on the masses and nodules of galenite.

As a rule, the residual clays are highly ferruginous. Limonite composes the principal part of them in some of the mines, and it was

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derived, in part at least, from the oxidation of the original sulphide iron pyrite, disseminated through the limestone in association with galenite and sphalerite. It is usually of good grade, and occurs so extensively in some of the mines formerly worked for zinc ores, that attention is now given entirely to the mining of the iron ore.

So far as known, there are no igneous instrusions found within the limits of this region with which to connect the ores. While it is true the ores are related to the folding and faulting of the region, there appears no good reason for regarding the ores as having been derived from profound depths within the interior of the earth, and later introduced into the limestone from solutions. Indeed, the evidence is against that source of the material, for, when ore deposits have been formed by such a process, they are usually associated with a characteristic set of minerals, such as compounds of arsenic, antimony,

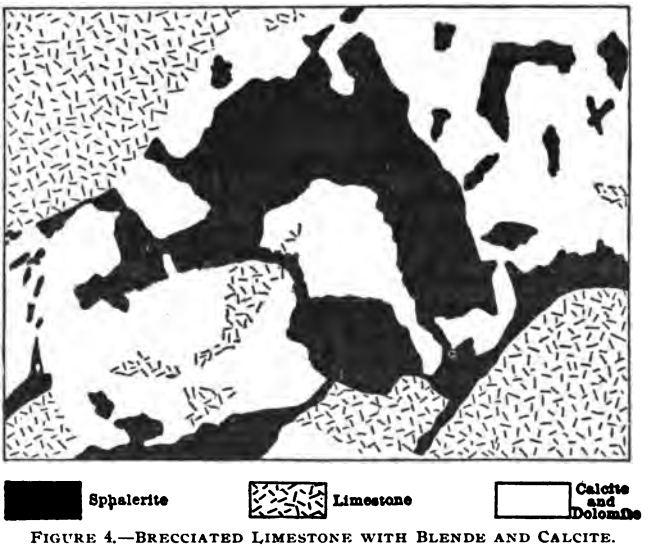

FIGURE 4.—BRECCIATED LIMESTONE WITH BLENDE AND CALCITE.

and silver, and frequently fluorspar, etc., all of which, with the exception of barely more than a trace of fluorspar, are here entirely absent.

The Cambro-Ordovician limestone is the only formation in the district that is positively known at present to contain lead and zinc ores. Other limestones have good development over parts of the district, and apparently offered equally as good advantages for ore deposition as the Cambro-Ordovician. There appears no real reason why the lead and zinc deposits should have been deposited in one formation and not in another, except that the source of the material was limited to the single formation in which they have been concentrated and localized, and in which they are now found. It further seems unnecessary to appeal to highly heated waters from profound depths, or from connection with igneous intrusions as a source of the material, since, as already stated, the field evidence is against such a process.

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The sulphide ores, including zinc blende, galena and pyrite, all closely associated, uncovered in the vicinity of No Business and Kimberling Creeks, show a predominance of zinc blende of remarkable purity, the pyrite being distributed through the limestone in quantity insufficient to be harmful. The following analysis of a specimen of the blende from No Business Creek, above Holly Brook, indicates the general character of the ore:

Zinc	63.07	per cent.
Sulphur	32.16	" "
Silica	.21	" "
Lime	.12	" "
Iron	4.44	" "

Limonite is the principal iron ore in association with the zinc ores, white hematite and the black oxide of manganese are less frequent associates. A map of Southwest Virginia and East Tennessee, Figure 5, shows the general distribution of lead and zinc ores, the deposits being indicated by the heavy dots.

IRON.

Red hematite (70 per cent. of metallic iron), brown hematite (60 per cent. of metallic iron), magnetite (72 per cent. of metallic iron) and carbonate (48 per cent. of metallic iron) iron ores, corresponding roughly to the minerals hematite, limonite, magnetite and siderite, have a more or less general occurrence throughout Southwest Virginia. Silica, lime, alumina, phosphorus, sulphur, manganese and titanium constitute the chief impurities of these ores. The Oriskany limonite, limestone limonite, Blue Ridge limonite, fossil hematite, Blue Ridge hematite, pyrite gossan, pyrrhotite and limestone magnetite constitute the principal iron ores of the region. Bland, Tazewell, Smyth, Wythe, Pulaski, Montgomery and Giles counties have the Oriskany and Clinton horizons on the slopes of their mountains which carry ore. The Oriskany ore deposits give greater promise than the other iron deposits of Virginia, because of their extent, continuity and depth, combined with the fact that they yield a fair grade of ore. The Valley ores, which are second in importance to the Oriskany, have probably reached their greatest development, as few new deposits remain to be discovered. The mountain ores for the most part occur in small, discontinuous deposits; but, in many places in Bland and adjoining counties a number of such deposits are grouped together and become of commercial importance. The Oriskany brown ores are the most important in the district, and are limited to a definite horizon, in the Helderbergian limestone, immediately below the Oriskany sandstone. Major John T. Hamlett, a leading authority on the Oriskany rocks and their contained ores, says: "But it is along the lower flanks of the several mountain chains and on the slopes of the intervening ridges that the most important features of the district are found. Here the formation is made up of coarse gray and brown sandstones, and everywhere throughout their locality in this section they carry with them the heaviest, most persistent and valuable

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strata of brown iron ores known in the United States. Their outcrops so frequently and extensively displayed along the base of every mountain and on the slopes of every intermediate ridge, point out the existence of a series of continuous beds of ore that are of great thickness and which extend for many miles." A selected sample of this ore taken from Cluxi, near Laurel Creek, analyzed as follows:

Sesquioxide of Iron	79.17 per cent.
Silica	2.16 " "
Sulphur	.366 " "
Phosphorus	1.127 " "

Magnificent outcrops of the ore appear on the slopes of Flat Top Mountain, above No Business Creek.

COAL.

The Virginia coal deposits of Carboniferous age include all deposits found west of the Blue Ridge. The Montgomery-Pulaski and Bland-Wythe counties areas are Lower Carboniferous in age. The Virginia portion of the Appalachian coal field, which includes the extreme southwest counties and to which the State owes its high rank as a coal producer, is Upper Carboniferous in age. The Southwest Virginia coal field forms the southwestern part of the Kanawha basin and comprises Buchanan, Dickenson, Lee, Russell, Scott, Wise and Tazewell counties, extending into Bland County. Of these Wise and Tazewell counties are at this time large producers, while the remainder of the territory contains large reserves of coal awaiting further development and transportation facilities. The Virginia portion of the Appalachian coal field is estimated to contain a supply of at least 25,000,000,000 short tons of coal, the Pocahontas and Big Stone Gap coal fields having been thus far developed. Numerous coal beds are found within the total vertical limits of the geological formations composing the Pocahontas field, one of which beds exceeds 11 feet in thickness. The superior quality of the Pocahontas coal has established it as the best steam coal in the world, and a producer of excellent coke. The Big Stone Gap coal field embraces parts of Lee, Scott and Wise counties and is much the largest producer of coal and coke in the State. This field has eight seams of coal, ranging in thickness from 3½ to 12 feet, included within a vertical distance of about 1,200 feet, and produces more than 80 per cent. of the coke made in the State. Of the numerous Lower Carboniferous coal areas known in Virginia, the Montgomery-Pulaski field is much the most important one. The mines are opened along the slopes of Brush, Price, Cloyd and Little Walker Mountains. The rock series consists of a variable thickness of sandstone, conglomerate and shale, dipping at angles ranging from 25° to 45°. The Bland-Wythe counties coal field has promising seams appearing in the Price sandstone near Bland Court House, Sharon Springs and in the western part of Bland County; and to the south of Little Walker Mountain, in Wythe County. Geological conditions point unerringly to the conclusion that coal-bearing beds, the extensions of the beds beneath the Pocahontas or Flat Top, the

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Big Stone Gap, the Montgomery-Pulaski counties and the Bland-Wythe counties fields, are to be found at varying depths but of continuous habit, throughout the entire territory bounded by the aforementioned fields. None of the formation can be traced through the entire field or territory, and in general the formations consist of overlapping lens-shaped beds, which explains the gradual thickening and thinning. On account of this variation it is difficult to correlate different beds throughout the entire region, or even in the restricted portion of Bland County. The last word in the correlation problem cannot be said until the large undeveloped areas intervening between the developed regions have been thoroughly explored.

The scarcity of fossil marine organisms of the coal-bearing rocks of this region indicates that the basin was probably separated from the sea and consisted in large part of fresh water lagoons and extensive swamps in which the vegetable matter since consolidated into coal was accumulated, and over which the sand and mud constituting the large part of the formations were distributed. It is possible that rivers played an important part in the distribution of the greatly diversified sediments of the coal-bearing rocks, for the existence of extensive peat swamps implies a land surface of slight relief, and a close succession of beds of coal, sandstone, and shale. The sandstone and shale were formed from the waste from the land, and show that the peat swamps were frequently invaded by rivers or lakes and occasionally by the sea. The great and probably rapid accumulation of sediments was accomplished by large streams, and it is possible that these streams may have been agents of wide distribution as well. The streams flowing from the land to the east of the swamp, which was above water level, carried the waste from the surface into the narrow basin in which the coal and accompanying rocks were forming. The rock floor underneath the Appalachian trough gradually sank and allowed the accumulation of material above it to extend farther and farther to the west, each succeeding bed overlapping that which was laid down previously. This accounts for the gradual thinning toward the west of both the rocks and the coal deposit. The generalized section, Figure 6, shows the general relation between the coal measures, in the regions indicated, as far as developed. This section must not be considered as a conclusive or definite section, as it simply expresses the general tendency of the measures to thin out toward the west and northwest.

TIMBER.

New River, tributary to the Ohio through the Kanawha, drains the eastern portion of the Appalachian Plateau. The sources of the tributaries are at elevations of from 3,000 to 5,000 feet, but below the junction of the North and South forks the river valley has an altitude of only 2,000 to 2,500 feet. The topographic features are deep, narrow valleys and ravines, with irregular intervening hills and mountains, among which are a few isolated having an altitude of 5,000 feet and upward, and occasional narrow flats along the larger streams. Many of the old hill fields have been exhausted by

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close pasturing, and the soil is being rapidly removed by erosion. About 55 per cent. of the territory is wooded. The forests of large area are limited to the higher altitudes, and the proportions of the various species composing the forests are as follows:

Oaks	45 per cent.
Chestnut	20 " "
White pine	2 " "
Hemlock	4 " "
Spruce	1 " "
Poplar	2 " "
Ash	2 " "
Buckeye	2 " "
Linn	3 " "
Black gum	1 " "
Beech	1 " "
Birch	3 " "
Maple	3 " "
Hickory	1 " "
Locust	1 " "
Black pine	1 " "
Other species	8 " "

The outlying isolated wood lots, surrounded by cleared land, are noticeably in better condition than the larger wild areas in the mountains. About 2,500,000 feet of timber at Cluxi, red oak and chesnut oak predominating, and averaging about 6,000 feet B. M. to the acre, with an excellent bark for tanning purposes, may be taken as an indication of value. The following species on this property have been cruised, and conform to the foregoing table of percentages: *White pine* (Pinus strobus), *Black spruce* (Picea mariana), *Hemlock* (Tsuga canadensis), *White oak* (Quercus alba), *Chestnut oak* (Quercus primus), *Black oak* (Quercus velutina), *Cucumber tree* (Magnolia acuminato) and *Yellow poplar* (Liriodendron tulipifera).

The Director of the United States Geological Survey, in endorsement of the foregoing, says: "In its geographic and geologic relations this area forms a part of the Appalachian province, which extends from the Atlantic coastal plain on the east to the Mississippi lowlands on the west and from Central Alabama to southern New York. All parts of the region thus defined have a common history, recorded in its rocks, its geologic structure, and its topographic features. The Appalachian province as a whole is broadly arched, its surface rising from an altitude of about 500 feet along the eastern margin to the crest of the Appalachian Mountains, and thence descending westward to about the same altitude on the Ohio and Mississippi Rivers. Each division of the province shows one or more culminating points. Thus the Appalachian Mountains rise gradually from less than 1,000 feet in Alabama to more than 6,600 feet in western North Carolina. From this culminating point they descend to 3,000 feet in Southern Virginia, rise to 4,000 feet in Central Virginia, and again descend to 2,000 feet on the Maryland-Pennsylvania line. The Appalachian Valley shows a uniform increase in

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altitude from 500 feet or less in Alabama to 900 feet in the vicinity of Chattanooga, 2,000 feet at the Tennessee-Virginia line, and 2,500 or 2,700 feet at its highest point, on the divide between the New and Tennessee Rivers. From this point it descends to 2,200 feet in the Valley of New River, 1,500 to 1,000 feet in the James River basin, and 1,000 to 500 feet in the Potomac and Susquehanna basins. These figures represent the average elevation of the valley surface, below which the stream channels are sunk from 50 to 250 feet, and above which the valley ridges rise from 500 to 2,000 feet.

The amount of uplift which this region has suffered in late geologic time is easily determined by the elevation at which the various peneplains now stand above sea-level, from which they formerly sloped gently upward. The total uplift since Cretaceous time has been from 3,000 to 3,500 feet, the sum of two general movements, of which the later was 2,600 feet. Besides the general peneplains, this region possesses a well-developed local base level, entirely independent of the general surrounding conditions. This is Burke Garden, a unique feature, a garden in a wilderness of sharp ridges and narrow valleys. It is a limestone area surrounded by mountainous walls of hard sandstone. Wolf Creek has cut a gorge on its northern side, through which its surplus waters are discharged, but the removal of the calcareous rocks within the barrier progresses as fast as the creek can cut its gorge; hence the floor of the garden is planed to the level of the outlet of the draining stream. The ridges formed by the upturned edges of the hard rocks are generally very narrow and straight, and between them narrow valleys are excavated in the softer rocks. The steepness of the slopes, and the great depth to which these valleys are eroded, indicate that a large portion of the elevation has occurred in very recent times. The most important valleys in this territory are (1) Bland-Sharon Springs Valley, (2) Burke Garden, and (3) Clinch River Valley. In the coal field the country is barren in the extreme, and before the development of its coals barely furnished food for the scanty population. This region, originally a table-land, is now almost completely dissected. The streams flow in narrow V-shaped ravines, above which the divides rise from 500 to 1,000 feet, in narrow, irregular lines of knobs showing little resemblance to the original even surface. The major portion of this territory is within the New River basin and is drained by Bluestone and East Rivers and by Wolf and Big Walker Creeks. Wolf Creek, rising in Burke Garden, flows east along the southern base of Rich Mountain to Rocky Gap, where it is joined by Clear Fork and Laurel Creek, forming quite a large stream. From this point of junction it flows directly to New River along a sharply cut valley at the northern base of Wolf Creek Mountain. Big Walker Creek drains the broad open valley about Bland, and east of this territory unites with Little Walker Creek, which drains the area between Big and Little Walker Mountains. South of Big Walker Mountain a small area is drained by Reed Creek, another branch of New River.

All of the rocks appearing at the surface within the limits of the Pocahontas territory are of sedimentary origin—that is, they were deposited by water. They consist of sandstone, shale, and limestone,

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having an average total thickness of 17,000 or 18,000 feet and presenting great variety in composition and appearance. The materials of which they are composed were originally gravel, sand, and mud, derived from the waste of older rocks, and the remains of plants and animals which lived while the strata were being laid down. The sea in which these sediments were laid down covered most of the Appalachian province and the Mississippi basin, but it probably varied from time to time within rather wide limits. As a rule, the younger rocks are limited in their outcrop to the northwestern side of the Appalachian Valley, whereas the older rocks are more generally exposed along its southeastern side. Whether this is due to the more extensive folding of the latter portion, by which the lower rocks have been brought within reach of erosion, or to the early folding and elevation above sea-level of the southeastern portion and the non-deposition of the later sediments over this land area, is as yet an unsettled question. In this territory, however, Cambrian rocks occur on the northern edge of the valley at the eastern end of an extensive anticline which, as it extends westward, is faulted in such a manner that the Cambrian rocks are thrust upon the Coal Measures.

Immediately overlying the Clinch sandstone and forming the southern slope of the ridges is a mass of shale and sandstones, varying in thickness from 15 feet in Cove Mountain on the Wytheville and Bland turnpike, to probably 400 feet on East River Mountain. The larger part of the formation is composed of sandy shale and ferruginous sandstone or fine conglomerate. In Cove Mountain, where the minimum measure of 15 feet was obtained, the base of the formation, consisting of sandy shale, is alone preserved; the upper portion appears to be entirely absent, either through non-deposition or through subsequent erosion. A coarse, white sandstone, about 40 feet in thickness, forms the extreme top of the Rockwood formation. Occurring as it does between easily erodible formations, it is frequently the only stratum showing in outcrop, and affords an excellent guide to the stratigraphy. This is quite important, since the two adjacent formations are the principal ore-bearing strata of the region.

Above the heavy Rockwood sandstone occurs a group of strata of very diverse characteristics but practicably inseparable in the field. In the Kimberling Wilderness, near the eastern edge of the area, the series is about as follows: (1) Overlying the Rockwood sandstone are 30 or 40 feet of blue limestone, varying from blue calcareous shale at the base to heavy blue limestone at the top. (2) This is succeeded by a very coarse ferruginous sandstone, greatly resembling some of the heavier beds of the Rockwood formation. At Holly Brook, it is 15 or 20 feet in thickness, and is made up of quartz pebbles about one-eighth of an inch in diameter, cemented by iron oxide. (3) Above the sandstone is a cherty limestone, or rather, a mass of chert 30 or 40 feet in thickness, which is everywhere present along the line of outcrop of thin formation and is frequently the only guide to the subjacent strata. (4) Above the chert is an indefinite thickness of yellow or green fossiliferous sandstone. In the Kimberling Wilderness, pebbles of limestone, evidently derived from the lowest number of this series, are found imbedded in the green sandstone.

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The limestone portion of this formation is generally classed as Lower Helderberg, and the upper sandstone portion as the Oriskany. This is no doubt correct, and were they everywhere as plain as on No Business Creek, they could be separated into two formations. They generally outcrop in the valley at the southern base of the Clinch ridges, and are usually badly covered by the debris from the sandstones forming the crest. Under such conditions, two members are usually seen in outcrop—the chert and the ferruginous sandstone—and the observer is left to determine the presence or absence of the other members from the soil on the hill slopes. The existence of the conglomerate at this horizon on No Business Creek indicates that immediately following the deposition of the limestone occurred an elevation of at least a portion of this region above sea-level, and that

FIGURE 5.—MAP OF SOUTHWEST VIRGIRNIA AND EAST TENNESSEE, SHOWING DISTRIBUTION OF THE ORES OF LEAD AND ZINC. THE DEPOSITS OF LEAD AND ZINC ARE INDICATED BY HEAVY DOTS.

from the land thus formed were derived the limestone pebbles. If this be correct, parts of the Pocahontas territory may have been dry land, upon which the green sandstone was never deposited, while other portions of it may not have been so affected and deposition may there have gone on uninterruptedly.

Overlying the Giles formation is a great series of Devonian shales. These begin at the base with black, carbonaceous shale, which is replaced higher up by green, sandy shale, and this in turn by thin-bedded, green sandstones, shale, and conglomerate. The black, carbonaceous shale at the base is a variable stratum from 400 to 600 feet in thickness, which passes into the green shale above by insensible gradations and interbedding. No definite line of demarkation between them can be drawn. This shale, being easily erodible, forms valleys, among which Little Walker, Hunting Camp, Wolf, Laurel, and Dry Creeks being the most prominent. The Kimberling shales

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are named from Kimberling Creek, which, in Bland County, flows through a wild and rugged region formed by these shales, and widely known as the Kimberling Wilderness. The base is indefinite, and the upper limit is somewhat uncertain. The green sandstones, sandy shales and conglomerates pass almost imperceptibly into the sandstones and shales of the coal-bearing formation of Lower Carboniferous age. There is usually a slight difference in color and character of the sandstones of these formations, which determines the boundary-line. The heavy beds of the Price sandstone are typical Coal Measure sandstones—coarse, yellow, and cross-bedded. All beneath are green and thin-bedded except the conglomerates.

The division-line between Devonian and Carboniferous rocks in this region is arbitrary, depending upon minor differences in the sandstones, which may or may not be constant over larger areas. But since the shales below are clearly Devonian, and the coal-bearing strata above clearly Carboniferous, it is highly desirable to separate them, even though the line be drawn arbitrarily. The coal-bearing formation is named from Price Mountain, in Montgomery County, where the coals have been profitably mined for a number of years. The formation consists of sandstones, shales, and coals, and in general appearance is almost identical with the measures in the coal field to the northwest. It is limited in its otucrop to the southern portion of the territory, across which it is exposed in two lines of outcrop. One, north of Big Walker Mountain, extends westward from Bland across the entire territory; and the other, south of the same mountain, crosses the southeastern corner of the territory, forming the southern slope of Little Walker Mountain. The upper portion of this formation is usually absent through faulting, so that the next succeeding formation has but a limited outcrop. It is a bright-red shale, which attains a great development in th vicinity of Pulaski, Pulaski County, from which occurrence it is named. In thickness it varies from a maximum of 300 feet on the eastern side of this territory to 20 feet or less on the western edge. The Pocahontas seam of coal is the most prominent feature, and, since it has been carefully traced throughout the entire coal field of this territory, forms a reliable local horizon for mapping purposes. All the rocks, from the top of the red shales up as far as the roof of the Pocahontas seam, are included in one group and named from the place at which this important coal was first opened. Two or three coal seams are known in the lower portion of this formation, but conditions do not appear to have become especially favorable for the growth of coal plants until the close of the deposition of the formation and the beginning of the deposition of the vegetable matter which has since been consolidated into the Pocahontas coal. This seam varies in thickness from about 10 feet at Pocahontas to 4 feet 6 inches on the headwaters of the Guyandot River, in the northern part of the field. The Pocahontas formation appears to hold a constant thickness of 360 feet throughout this entire area. The strata above the Pocahontas seam do not differ essentially from those below. They consist of alternating sandstones, shales and coals, but with no marked beds. Immediately overlying the Pocahontas seam is a heavy ledge of sandstone, 50 or 60 feet in thickness, which has

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served as an excellent guide in prospecting for this seam. Above this sandstone is the same monotonous succession of beds for a distance of 380 feet to a second general coal horizon, which has been traced continuously to New River.

Each subdivision of the Appalachian province is characterized by a distinctive type of structure. In the plateau region and westward the rocks are generally horizontal and retain their original composition. In the valley the rocks have been steeply tilted, bent into folds, broken by faults, and to some extent altered into slates. In the mountain district faults and folds are important features of the structure, but the form of the rocks has been changed to a greater extent by cleavage and by the growth of new minerals. In the valley region the folds and faults are parallel to the old shore-line along the Blue Ridge, extending in a northeast and southwest direction for very great distances. Some of these faults have been traced 300 miles, and some folds even farther. Many folds maintain a uniform size for great distances, bringing to the surface a single formation in a narrow line of outcrop on the axis of the anticline, and another formation in a similar narrow outcrop in the bottom of the syncline. The folds are also approximately equal to one another in height, so that many parallel folds bring to the surface the same formation. The rocks dip at all angles, and frequently the sides of the fold are compressed until they are parallel. Where the folds have been overturned, it is always toward the northwest, producing southeastern dips on both limbs of the fold. In the southern portion of the Appalachian Valley, where this type of structure prevails, scarcely a bed can be found which dips toward the northwest. Out of the overturned folds the faults were developed, and with few exceptions the fault planes dip toward the southeast and are parallel to the bedding planes. Along these planes of fracture the rocks moved to varying distances, sometimes as great as 6 or 8 miles. East of Rocky Gap the structure of Buckhorn Mountain is extremely complicated. It consists of a number of irregular, closely appressed folds which have been badly crushed and thrust upon other folds in a similar condition, the whole forming a most confused mass of broken and folded rocks. This belt is limited on the southeast by a fault which originates near Shawver Mills and develops eastward, until at Rocky Gap the stratigraphic throw of the fault is such that the Shenandoah limestone is brought in contact with the Bays sandstone. The next succeeding belt, limited on the northwest by the Rocky Gap fault and on the southeast by the Bland fault, is one of broad, open folding. In general it is a flat synclinal basin with its southern limb cut off by the Bland fault. In this broad basin numerous arches or dome-shaped anticlines have developed, which form a most interesting part of the structure. At the eastern edge of the territory this fold is a simple syncline, but very broad and shallow. East of Kimberling Springs a low dome brings up, in a limited area, the Romney black shale and the cherty member of the Giles formation. At Hicksville a very pronounced arch breaks the monotony of the syncline, and forms, by its gentle uplift the peculiar mass called Round Mountain. The axis of this fold pitches down opposite Grapefield, forming a neck between

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Round Mountain and Burke Garden. Again it expands in a large dome-shaped anticline from which erosion has produced Burke Garden. This fold dies out irregularly to the west in several small folds, all of which end before reaching the edge of the territory. A nearly symmetrical anticline, known as Thompson Valley, is slightly offset from this fold and extends westward for a great distance. The southern limb of the anticline forms Clinch Mountain, which extends southwestward nearly to Knoxville, Tennessee. The basin deepens as it approaches the Bland fault, and the basal member of the Carboniferous series comes in next to that line. This fault is quite irregular, having two pronounced offsets corresponding to the great northerly bend in Big Walker Mountain. The latter mountain is but the northern limb of a similar fold which has been almost obliterated by the faulting of its southern limb and the overthrust of Cove Mountain upon this trough. Of the seven longitudinal faults, occurring in this territory, at least two are far-reaching toward the southwest, where faults are the rule and open folds the exception. These extensive breaks are the St. Clair and Bland faults. The others simply disappear in anticlinal folds or merge with the more extensive faults.

The importance of this region is chiefly owing to its mineral resources. These are not varied, but, so far as known at present, include coal, iron, marble, clay, and stone. By far the most prominent of these is coal, which has given to this region its economic importance. The northern portion of the Pocahontas territory embraces almost all of the developed portion of the Pocahontas or Flat Top coal field. This is the most important mineral district in the region, and it is an important factor in the coal production of the United States. Although of comparatively recent development, the field has experienced continued and unprecedented prosperity. In 1882 the New River branch of the Norfolk and Western Railroad was constructed to Pocahontas and mining on a commercial scale was begun. The opening of new mines and the building of coke ovens still continue, and probably in the near future will extend to other valleys than those in which operations are at present carried on. The formations in which coal beds occur are the Pocahontas, Quinnimont, and Sewell, having a total thickness of 1,190 feet. These contain a number of seams of workable thickness. In this territory the principal ores of iron are associated with the Rockwood and Giles formations. The former is the great ore-bearing formation of the South, and is widely known from the red fossil ore which it generally contains. Most of the sandstones of the Rockwood formation carry a large amount of iron. In many places the shales of this formation carry a hematite ore of promising appearance, and apparently in sufficient quantity to be of commercial value. This is the famous Oriskany ore of northern Virginia, but in the Pocahontas field it appears to be more intimately associated with the limestone stratum than with the sandstone. From the presence of limestone pebbles in the Oriskany sandstone, as well as from the mode of occurrence of the ore itself, it seems probable that the ore is due to subaerial disintegration of the limestone which then formed a land surface and the segregation of the ferruginous matter in the residual

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clay. This probably occurred contemporaneously with the deposition of the sandstone; so the ore may be classed as Oriskany in age, though formed directly from the Helderberg limestone.

The Chickamauga limestone, which in East Tennessee carries the great deposits of variegated marble, is generally a blue limestone, carrying marble at the northern base of Big Waker Mountain, in the great bend between Bland and Sharon Springs. The marble is coarsely crystalline and of a light-gray color. It occurs in massive beds, and may be a fine building stone. It has never been developed, except for local use.

Coal seams in the Price sandstone are known in the vicinity of Bland and Sharon Springs and near the southwestern corner of the territory; also in rocks of the same age south of Little Walker Mountain."

In further endorsement of the geological findings in Bland County and surrounding territory, Thomas Leonard Watson, Ph.D., State Geologist, says: "Virginia is divided into three major provinces: (1) The Coastal Plain or Tidewater region; (2) A central plateau region, designated the Piedmont Plateau; and (3) A Western or Mountain region, designated the Appalachian Mountain province. The western or Mountain province is divided into three well-marked physiographic belts, which extend the entire length of the province in the State from northeast to southwest. These are named in order from east to west the Blue Ridge, the Great Valley, and the Alleghany Ridges. The topography of the Appalachian province is varied and picturesque. The Great Valley region is composed throughout of Paleozoic sediments, which range in age from Cambrian to Carboniferous. The principal rock-types include limestone, shale and sandstone. The distribution of the formations over the Great Valley region (in the New River District) are shown on the section map in Figure 1. The simple horizontal arrangement of alternating hard and soft beds of this region which prevailed at the time of deposition, have been greatly complicated by folding and faulting. The present attitude of the beds indicates that in general they have been arched into great folds and troughs whose axes extend, as a rule, in a northeast-southwest direction. Sufficient time has elapsed since the folding and faulting occurred for the rocks to be greatly eroded. The softer or less resistant rocks like shale and limestone were lowered more rapidly by erosion than the harder and more resistant rocks like sandstone, because the former rocks are in general valley-making while the latter are ridge-making. The formations are now exposed in long, narrow belts, the widths of which depend on the thickness of the formation and the angle of dip. As a result of the bending into arches and troughs of the beds and of subsequent erosion, the edges of the formations have developed as linear ridges and valleys, developing the well-known Appalachian type of topography. This dependence of topography on structure and lithologic character of the rocks is well illustrated in the present surface configuration of the Great Valley region. Structurally the southwestern Virginia area is very complex by reason of great folds and overthrust faults. Study of the region shows that it is traversed in a northeast-southwest direc-

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tion by not less than seven major faults and by a number of minor ones. These major faults are named in their order from east to west: (1) The Holston and Iron Mountain fault; (2) The Walker Mountain fault; (3) The Saltville fault; (4) The Copper Creek fault; (5) The Hunter Valley fault; (6) The Wallen Valley fault; and (7) The Poor Valley fault.

BUILDING STONES.

The production of building stone has long been an important industry in Virginia, and the output in some varieties, especially granite, has been used in many notable structures. A large variety and abundance of excellent stone occur widely distributed over the Piedmont and Mountain provinces of the State, including granite and gneiss; trappean rocks, some included as black granites, slate, sandstone and quartzite, limestone and marble. The Virginia *granites* are mixtures of feldspar, quartz, and biotite, with usually more or less of the white mica, muscovite. Under the name of *syenite* is included a crystalline granular rock which consists essentially of orthoclase, with or without one or more of the accessory minerals, mica, hornblende, or augite, and differing from granite only in the absence of quartz. *Gneisses* of granitic composition form one of the most widespread rock-types in the Virginia crystalline area. Structurally they vary from irregular banded rocks to regular banded forms like the gneiss of the Lynchburg area. Texturally they vary from fine to coarse-grained rocks. *Mica schist* is probably the most abundant type of crystalline rock occurring in Virginia. It is usually thinly foliated, composed essentially of mica and quartz with or without feldspar, and is quite variable in character. *Trap* or *diabase* occurs widely distributed over the crystalline area in Virginia, in scattered dykes penetrating the older rocks of the crystalline area. The fissures, filled with diabase, are irregular in trend, sometimes following and sometimes crossing the beds of sedimentary rock, the thickness of the diabase ranging from 10 feet to possibly 800 feet. Notwithstanding the wealth of diabase of excellent quality found in Virginia, only a few quarries have as yet been opened. *Diorite* is less abundant in Virginia than diabase, and its quarrying has been extremely limited, although it readily works out into blocks on account of its more or less gneissoid structure. *Slate* suitable for roofing and other purposes is found in many localities in Virginia. Of the slate areas worked, that of the Arvonia belt is the most important. The various *sandstones* and *quartzites* of the Mountain province are Cambrian, Silurian, Devonian and Carboniferous. The Paleozoic sediments comprise a vast thickness of rocks, principally sandstone, shale, and limestone. Many of the sandstone formations described are capable of producing stone desirable in all respects for concrete work. *Limestone* has wide distribution in Virginia, and is found in each of the three larger divisions. It has its greatest distribution in the province west of the Blue Ridge, where it is one of the dominant rock-types. There are inexhaustible supplies of limestone in the Mountain province of Virginia suitable for the various uses made of this rock. It has been extensively quar-

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ried over many parts of the area for use as a furnace flux, for lime-making in building and agriculture, for building stone, for road metal and ballast, and for the manufacture of cement, both Portland and natural. The limestones which have been quarried to a greater or less extent over the area west of the Blue Ridge are the Shenandoah, Chickamauga, Lewiston and Greenbrier. At the northern base of Big Walker Mountain, Bland County, between Bland and Sharon Springs, the Chickamauga limestone carries marble of coarse crystallization and of light gray color. It is found in massive beds and should prove to be a desirable building stone. One of the principal lines of outcrop of the Greenbrier limestone is along the border of the coal field. It generally consists of heavy blue limestone, cherty at some horizons, grading upward into thin beds of a light blue color, becoming decidedly shaly at its upper limits, and is abundantly fossiliferous. It varies in thickness, ranging from 900 to 1,700 feet.

NON-METALLIC MINERALS.

Pyrite, known also as iron pyrites, is found in granular masses of a brassy-yellow color. It occurs as disseminated grains through the rock mass; in contact positions between rocks of different kinds, especially between eruptive and sedimentary rocks; as fissure veins; and as lenticular bodies, sometimes of immense size, lying conformable, or nearly so, with the structure (foliation) of the enclosing rocks. More or less copper, usually a small fraction of 1 per cent. in the form of chalcopyrite, is invariably present, inextricably intermingled with the pyrite. Lead and zinc are present in traces at times and occasionally they are appreciable in small masses of the ore. *Pyrrhotite* or magnetic pyrite occurs as lenses in the crystalline schists and as well-defined veins, the best example of which is that of the "Great Gossan Lead" in Southwest Virginia. This well-defined vein of pyrrhotite, varying in width up to 100 feet, strikes southwestward from Floyd County a distance of more than 20 miles. An extensive plant has recently been completed at Pulaski for the purpose of utilizing the pyrrhotite of the "Gossan Lead" for both acid and iron-making. *Arsenopyrite* is found in association with pyrite and cassiterite in quartz-greisen tin-bearing veins, which penetrate coarse granite. Near the summit of the Blue Ridge in Floyd County, about 17 miles from Christiansburg, and at an elevation of about 3,200 feet above sea-level, a series of veins (lenses) of arsenopyrite in quartz-sericite schist occurs, which outcrop in places on the surface.

Fluorite, known commercially as fluorspar, is sparingly found associated with the ores of lead and zinc in the Cambro-Ordovician limestone of Southwest Virginia. *Silica* occurs as an essential constituent of granite, gneiss, and mica schist of the crystalline area. Deposits of diatomaceous earth are formed from the shells and tests of certain aquatic microscopic forms of plant life known as distoms, which have the power of secreting silica in the same manner as mollusks secrete lime-carbonate. Although formed at various geologic periods, the beds of known commercial importance of diatomaceous

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earth are of Tertiary age, a period which was apparently adapted to the growth of these organisims.

Ocher, the term applied to the earthy and pulverulent forms of the minerals, hematite and limonite, shows a variety of colors which depend in general upon chemical composition. More directly the natural colors of ocher depend on the degree of hydration and oxidation and the kind and amount of impurities. The red, yellow, and brown ochers are found. According to their natural colors or sources, various varieties are distinguished. *Manganese,* in the form of oxides (pyrolusite and psilomelane) is distributed through the clays in an irregular manner in the form of pockets or lenticular masses, rarely as distinct beds; as veinlets and stringers cutting the clays in all directions; as single nodules or concretionary masses assembled in the clays; and as small disseminated grains scattered through the clays. See Figure 3. The pockets show much variation in size and number; ranging from small nests to bodies yielding many tons of ore. The ore is usually partially or entirely crystalline, of a dark steel-blue color, and the nodular type, which prevails nearly always, displays the complete or partially layered or concentric structure of concretionary masses. Many outcrops and other indications of manganese ore are found in Craig, Giles, Bland and Tazewell Counties. Some of the ore has been mined to a limited extent in different places, but as yet no extensive developments have been made. These ores are usually associated with those of iron and are reported largely from the Oriskany horizon.

Feldspar, commercially valuable, occurs associated with quartz and mica, as coarse crystallizations in pegmatitic dikes or veins, cutting granites, gneisses, and crystalline schists. The openings made on these dikes show a variable ratio of the three principal minerals, mica, feldspar, and quartz. In places, the three occur in nearly equal amount; in others dominant feldspar and mica with very little quartz; and others still show dominant quartz and mica with little or no feldspar. Muscovite, the white mica, and biotite, the black mica, are most widely distributed. *Asbestos,* of the amphibole variety, is found in the granite or schistose rocks either in pockets or in more or less well-defined veins, a fact which considerably lowers the cost of mining it. It varies from white to greenish and woody-brown and its fibres are flexible and easy to separate. *Talc,* a hydrous silicate of magnesia, and *soapstone,* an impure form of talc, occur chiefly associated with the older crystalline rocks. In some cases soapstone has been derived from magnesian sediments by metamorphism. The quarrying of soapstone in Virginia has grown to be one of the important resources of the State, with every promise of greater expansion in the future. *Fullers earth,* including a variety of clay-like materials which have the property of absorbing greasy substances, probably results from the decomposition of the hornblendes and augites rather than the feldspars as in the case with ordinary clays. *Barite,* the sulphate of barium, in Bland County, occurs in the limestones, and is often found as superficially loose lumps and nodules of irregular shapes and sizes embedded in residual clays derived from the decay of the limestone. The mineral association of barite is with limonite, sphalerite, galenite,

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and occasional fluorite. At the Bertha Zinc Mines, barite is found in places as loose nodules embedded in the red clay, resulting from the limestone decay. In Southwest Virginia the *gypsum* deposits are associated with gray and purple clays in shales and shaly limestones of Lower Carboniferous age. A good supply of gypsum has been mined less than one-half mile south of the base of Little Brushy Mountain. It is quite similar to that mined at Plasterco and it contains very thin leaves of interlaminated gray crystals of the gypsum.

MINERAL WATERS.

The mineral waters of Virginia are an important source of revenue. Indeed, Virginia is par excellence a mineral spring State. All classes of mineral waters are found in the State. The thermal springs are entirely confined to the mountain region, and many of the best known springs in the State are there located.

CEMENT MATERIALS.

In general the entire Valley of Virginia is underlain by the Cambrian and Ordovician limestones, while the shales usually ouctrop

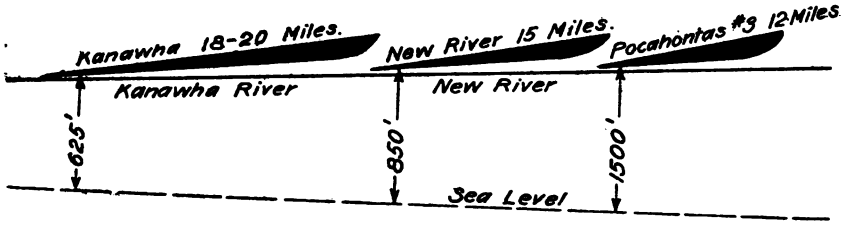

FIGURE 6.—GENERALIZED SECTION SHOWING THE GENERAL RELATION BETWEEN THE COAL MEASURES IN THE SEVERAL REGIONS AS FAR AS DEVELOPED.

along the base of the mountains bounding it. In a similar manner, many of the valleys west of the Great Valley show these limestones and shales, higher formations occurring on the separating ridges. From a geological standpoint, Southwestern Virginia may be considered as composed of elongated, narrow, northeast-southwest blocks, in each of which strips exposing favorable cement materials are found. The portion of Giles County (adjacent to No Business Creek section of Bland County) occupied by Ordovician strata is large, as seen in Figure 1. The cement materials occur in the Pearisburg limestone and the lower portion of the Sevier shales. A detailed section of the Greenbrier limestone may be seen along the Norfolk and Western Railroad near Lurich, in Giles County. Here, all of the beds are fairly well exposed and the section may be considered as typical for the region.

CLAYS.

The State of Virginia contains a variety of clays, which are adapted to a variety of uses, but many of the deposits have remained un-

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developed, because little is known regarding them. The *residual* clays have been formed by the weathering of rocks, involving processes of disintegration and decomposition. As a result of this we find the residual clay overlying the parent rock from which it was derived. The *sedimentary* clays represent deposits which have been laid down under water, one layer on another, the materials composing them consisting of the products of rock decay, which have been removed by erosion from the land surface, and washed down into the lakes, or seas, where they have finally settled. These are abundant in both the Coastal Plain area, where they are usually of unconsolidated character, and west of the Blue Ridge, in which region they are mostly of a hard and shaly nature. They are widely distributed geologically, and the geological distribution agrees also somewhat closely with the geographical range. The mountain province, west of the Blue Ridge no doubt contains clay resources of great value, which however are, as yet, but little developed. Associated with the coals are many beds of shale, some of which appear very promising. These different shale deposits are indeed worthy of a careful and complete investigation and, when fully developed, will no doubt become a valuable source of revenue.

SAND AND MARLS.

Loamy sand as well as mixtures of coarse and fine sands, suitable for building purposes, has wide distribution and is found in considerable quantity along the stream courses. The mineral glauconite of the green-sand marls occurs as grains which frequently show themselves to be casts of foraminifera and other calcareous organisms; and as pointed out by Murray and Renard it is associated with terrigenous minerals, particularly orthoclase (feldspar) and muscovite (mica) and similar potash-bearing minerals. The glauconitic sands have wide distribution through the various geologic formations. The marls of this region belong entirely to the calcareous type. Some of these have had a limited use as a flux in iron-making, and, in places, they may offer possibilities for use in the manufacture of Portland cement.

COPPER.

The ores of copper have wide distribution over the State of Virginia, although there are at present but few producing mines. Probably the most noted Copper region of Virginia is in the southwestern portion of the State, in a belt of crystalline rocks passing through Floyd, Carroll, and Grayson Counties. The region is a part of the eroded Blue Ridge upland, marked by well rounded summits and deeply trenched streams. A careful examination shows the vein to be traceable for 18 miles. From one end to the other there are old pits whose dump heaps show the typical gossan ore, Figure 2, and as several of the old mine-workings can be continuously followed underground for miles running at a depth of from 20 to 60 feet below the surface, there seems little doubt that it is one of the greatest veins in the Appalachians. The vein consists essentially of pyrrhotite with disseminated particles and stringers of chalcopyrite. It is not in every

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place a solid mass of pyrrhotite from wall to wall, but rather a series of layers, partly of pure pyrrhotite admixed with more or less micaceous material, an altered form of the country rock. The vein varies in width from 32 to perhaps 100 feet. A diamond drill hole was put down to a depth of 524 feet on the vein, proving the deposit to a depth of 734 feet below the outcrop. In places, the vein filling comprises rock fragments of varying character cemented by the sulphides, principally pyrrhotite. These fragments are often well rounded, sometimes, subangular and include rock types not seen on the surface either at the vein or nearby. The Pulaski Mining Company has been mining the pyrrhotite for acid-making, with occasional shipments of the secondary black copper concentrated below the gossan.

ZINC AND LEAD.

The known commercial deposits of zinc and lead in Virginia, excepting the single deposit in the southwestern part of Albemarle County, are limited to the Valley province, west of the Blue Ridge. All mining and prospecting for zinc and lead ores in this province have been confined to the western half, extending from and including Roanoke County on the east to and including Scott County on the southwest. Ores, both of zinc and lead, are known to occur in the following southwestern counties of the State: Roanoke, Montgomery, Pulaski, Wyeth, Smyth, Bland, Tazewell, Russell, and Scott. Geologically the occurrence of zinc and lead ores in Southwest Virginia is limited to the magnesian limestone of Cambro-Ordovician age, known as the Shenandoah or Valley limestone. The commercial deposits of these ores occur near the eastern side of the Valley. The Map, Figure 5, shows the location of the principal openings for zinc and lead in Southwest Virginia and East Tennessee. The ores include (1) the original sulphide forms sphalerite, sulphide of zinc, galenite, the sulphide of lead, pyrite, the sulphide of iron, and in several places chalcopyrite, the double sulphide of iron and copper; and (2) the secondary oxidized forms which have been derived from the original sulphides and occur in the residual decay of the limestone. These include calamine, hydrous silicate of zinc, smithsonite, carbonate of zinc, and cerussite or carbonate of lead. The associated non-metallic minerals, named in the order of their importance, are dolomite, calcite, barite, fluorite, and quartz. At the principal Virginia zinc mines *galenite* occurs in fairly large amounts in intimate association with sphalerite. Its usual occurrence is granular and massive-granular less frequently in the form of crystals. Cerussite occurs distributed through the residual clays of the limestones as stringers and small irregular masses. *Sphalerite* is found usually below the ground water-level, and occurs in the form of disseminated grains, masses and stringers in the magnesian limestone and similar form. *Smithsonite* occurs in the residual clays derived from the magnesian limestone concentrated, usually, in the bottom portions of the clays and resting immediately on the irregular weathered surface of the limestone. *Calamine* occurs in the residual clays, usually in the bottom portions. Much of the calamine formerly mined at Bertha is re-

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ported to have been in sheet form, rarely in contact with the limestone but concentrated several inches away from the limestone surface and having the intervening space filled with a mixture of loose powdery calamine and smithsonite. *Buckfat* is the name applied by the miners to a mixture of clay with the minerals calamine and smithsonite. The zinc content shows wide variation. It is both hard and soft. Pyrite is a frequent associate of galenite and sphalerite, occurring in the fresh limestone below the belt of oxidation. Limonite comprises the principal iron ore mined in association with the zinc ores. Hematite is less common than limonite. Black oxide of manganese is a frequent associate in some of the mines. The zinc and lead district of the Great Valley region of Virginia and Tennessee is one of intense deformation—folding, faulting, and brecciation. Mineralization has not taken place through all parts of the breccia-zones which follow the anticlines, but only along some of the zones in places and at irregular intervales have the ores accumulated. Whenever the ores have been found they have been noted in some part of an anticlinal fold in or near a faulted breccia-zone. The ores are accordingly of breccia type.

IRON.

The iron of the *Oriskany* ores was originally disseminated in the Devonian shale. As this shale was eroded the iron was taken in solution, carried down and deposited in any favorable place. Ordinarily this place was the upper portion of the Helderberg limestone. In some cases there was a direct replacement of the limestone by the iron and in other cases the iron was deposited in the space from which the limestone had been removed by solution. The iron rarely occurs in the sandstone in minable quantity. In the shale it has been deposited chiefly parallel to the bedding of steeply inclined strata. The outcrop of the ore is usually found on the lower slopes of the mountain a few hundred feet above the valley bottom. Along the base of the mountain on the strike of the formation the ore may appear with more or less development for miles. Continuous ore-bodies with fairly constant thickness have been worked for half a mile. The thickness of the ore-body has been largely controlled by the original thickness of the upper layer of the limestone at that point. Usually this is replaced to its full width. From 8 to 35 feet are usual thicknesses of the ore-body. *Limestone limonite* (limonite and mountain ore) is well adapted to use in charcoal furnaces, and is only second in importance to the Oriskany ores. The chief occurrence of this ore is in the New River-Cripple Creek area. It has been mined most extensively in the Counties of Wyeth and Pulaski. In the New River-Cripple Creek area where this ore has its greatest development, the lower portion of the Shenandoah limestone is a pure limestone through a thickness of several hundred feet. Under the limestone there is a thin shale and under this a considerable thickness of quartzite. These strata have been deformed considerably by folding and some by faulting. Along the southeast side of the Valley and along several anticlinal valley ridges and other

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valley anticlinals, the upper limestone measures have been removed by erosion and the lower measures outcrop along the base of the slopes and the crests of the non-ridge-making anticlinals. In this area the New River and its branches have cut down 200 to 300 feet below the general level of the limestone surface. The land surface presents a series of oval domes and the ore is found mostly on the crests and upper slopes of these hills, several hundred feet above the major streams. *Limestone magnetite* is a secondary deposit in the limestone. In the limestone about these ores in some instances there is iron carbonate which at the surface has been altered to limonite. In some instances the limestone about such deposits has been removed by solution, and lumps of magnetite of a few pounds weight are found scattered through the clay. Where the ore is well concentrated the magnetite is the highest grade ore in the State and usually has its phosphorus below the Bessemer limit. Bland County is a Mountain county and has the Oriskany and Clinton horizons on the slopes of East River, Buckhorn, Rich, and Walker Mountains, which carry ore.

COAL.

The construction of the Norfolk and Western Railway through Southwest Virginia, in 1882, opened up the famous Pocahontas Coal district. Likewise, the building of the Clinch Valley division of the Norfolk and Western Railway, nine years later, marked the beginning of the development of the Wise County coal district. Coal was mined in the Montgomery-Pulaski Counties area prior to the Civil War. This area includes Price and Brush Mountains in Montgomery County, and Cloyd and Little Walker Mountains in Pulaski County. The Bland-Wythe Counties area includes a small area in the southern part of Bland County and in the northern part of Wythe County. The Southwest Virginia area forms the Southeastern portion of the Kanawha basin, and comprises the Pocahontas or Flat Top and the Big Stone Gap coal fields. All the deposits of the Mountain province belong to the Paleozoic (Carboniferous) coals. Of the numerous Lower Carboniferous coal areas, The Montgomery-Pulaski field is the most important. The area is located 30 to 50 miles west of the City of Roanoke. In the Montgomery County portion of the area the mines are opened along the south slope of Brush Mountain and on the slopes of a parallel ridge locally known as Price Mountain. In Pulaski County developments are made on the slopes of Cloyd and Little Walker Mountains, which are a continuation southwestward of Brush Mountain in Montgomery County. The coal area lies near the northern border of the two Counties and is crossed by New River which is the dividing line between the Counties. The rock series consists of a variable thickness of sandstone, conglomerate, and shale, dipping at angles varying from 20° to 40°. The coal is the semi-anthracite variety of excellent quality. That from Price Mountain is harder, and consequently not so free-burning as the coal from Brush Mountain. A coal field of Lower Carboniferous or Pocono age is found in the southern portion of

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Bland County and in the northern portion of Wyeth County. The coal seams appear in the Price sandstone in the vicinity of Bland Court House, Sharon Springs and the southwestern corner of Bland County; and near and to the south of Little Walker Mountain. The rocks are usually highly tilted and are more or less crushed. The present era of railroad construction in this part of Virginia will witness, in the immediate future, extensive developments and mining of the enormous reserves of excellent coal hitherto undeveloped because of lack of railroad facilities. The Southwest Virginia coal field is vastly the largest, most productive, and most important in the State. It is estimated that the area of coal-bearing formations in this field comprise 1850 square miles, with probably 80 per cent. of it productive. The two principal coal fields in Southwest Virginia thus far developed are The Pocahontas or Flat Top and The Big Stone Gap. The coal-bearing strata of the Southwest Virginia field consist of beds of conglomerate or coarse sandstone, shale, and numerous seams of coal. Beneath this group of coal-bearing strata and to the southeast of the Pocahontas field, in the southern portion of Bland County and the northern part of Wythe County, is a coal-bearing series of rocks, principally the Price sandstone. Areas belonging to this horizon are found at intervals along the western side of the Great Valley in Virginia as far north as Frederick County. In the Pocahontas field a fault abruptly terminates the field on the southeastern border. Traces of the coal-bearing rocks, however, are still found to the east of the fault, indicating a greater eastern extension of the field. The beds show a general tendency to thicken toward the east.''

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